

# Trends in Evolving Technologies in the Operating Room of the Future

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## INTRODUCTION

Present-day operating rooms (ORs) are inefficient and overcrowded, and the turnover between cases is often lengthy and variable. New technologies and devices are often introduced haphazardly into an already technologically complex environment. Patient data and images are not well integrated or displayed in a timely fashion. This lack of integration of technology and information further strains the system, resulting in further reductions in efficiency. This, in turn, potentially impacts patient safety and costs. Improved integration of high technology, along with teamwork and enhanced communication and coordination among services, providers, and staff, is essential to improve efficiency, enhance safety, and reduce the cost of care.

Despite these daily realities, the traditional OR is being transformed as new technologies and paradigms are being introduced into the clinical environment. We will examine some of the current trends in patient management and developing technologies that are likely to continue to impact the OR environment and the OR of the future.

## CURRENT RELEVANT TRENDS

There is an ongoing migration from invasive to less invasive and even noninvasive procedures. Minimally invasive surgery, image-guided procedures, robotic surgery, and tele-surgery continue to replace traditional surgical procedures. Single-incision laparoscopic surgery and natural orifice transluminal endoscopic surgery techniques are continuing to evolve and transform laparoscopic procedures. Procedures once requiring general anesthesia

can now be performed with image-guided vascular access technologies and other endoscopic access techniques. Tumor ablation, instead of resection, is accomplished by use of imaging-guided radiofrequency ablation, microwave therapy, cryoablation, lasers and interstitial laser therapy, focused ultrasonography (high-intensity focused ultrasonography), and focused radiation (Gamma knife [Leksell Gamma Knife, Elekta, Stockholm, Sweden]).<sup>1,2</sup>

## THE IMPACT OF CURRENT TRENDS ON THE FUTURE

Patients will have less pain and shorter hospital stays, and fewer procedures will require general anesthesia during patient treatment. Some procedures will only require sedation. Traditional boundaries of the surgical space will blur. Endoscopic and endovascular procedures will replace certain surgeries. Many currently performed surgical procedures will only require an ambulatory setting, increasing demand for ambulatory/overnight facilities. There will be less need for the conventional multidisciplinary OR and more need for specialized imaging-guided procedure suites, hybrid ORs, endoscopic surgical/interventional suites, and endovascular surgical suites. These trends may promote either the scattering or assembly of interventional suites, or the dispersion or convergence of surgical services within the medical center, depending on their particular implementation and facility constraints. Evolution of new medical/interventional professions (eg, endoscopic surgeon or surgical interventionalist) is inevitable as practice and specialty boundaries blur with multidisciplinary techniques and clinical skills.

## THE FUTURE OF SURGICAL THERAPEUTICS

Surgical resections will continue to be replaced by ablations, minimally invasive procedures via natural orifices, and image-guided endovascular therapeutics. Surgical endoscopic procedures (natural orifice transluminal endoscopic surgery) will become safer and more prevalent because of the development of novel full-thickness closure technologies and the introduction of flexible endoscopic

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cameras and tools. Safe full-thickness en bloc resection of sessile polyps and early malignancies will replace major surgical resections. Morbidity will be reduced through the use of advanced tissue glues, sealants, hemostatic agents, and other novel technologies. Brachytherapy, radiofrequency ablation, selective targeted drug therapy, or totally noninvasive tissue ablations using magnetic resonance—guided focused ultrasonography ablation and CyberKnife (Colorado CyberKnife, Denver, Colorado, USA) ablation will enhance the capabilities of the surgical interventionist and will augment or replace more invasive alternatives. New devices and technologies with improved attention to ergonomics will improve the surgeon-tool interface, improving the ability for the surgeon to safely complete the tasks required.

## **ROBOTICS OF THE FUTURE**

Robotic systems will become less cumbersome, will become smaller and more compact, and will occupy less space. Robotic systems will possess enhanced haptic sensation abilities, tissue recognition, and real-time diagnostic abilities. The concepts behind the introduction of robotic surgery in the late 1990s and the beginning of this century were to reproduce the hand motions of a surgeon by increased degrees of freedom and with greater precision because of reduction of hand tremor, while providing enhanced visualization via high-definition 3-dimensional video images. These attributes will allow delicate accuracy and better-than-human performance. It will also be possible to perform surgical procedures that are limited only by available communication technologies even at extreme distances between the surgeon and the patient by computerized mediation of the surgeon's actual hand motions to the surgical instruments affecting the patient's tissue. The time lag between the primary motion and its result in the patient's body is the limit for the applicability of robotic systems in the case of the extreme distances in outer space. The near future will prove that realization of the attributes of enhanced surgical motion and enhanced visualization is possible by different technologies and separate, more inexpensive and less cumbersome systems. The remote telesurgical concept was pioneered by Dr. Jacques Marescaux of Strasbourg in 2001 and later by Dr. David Williams, a Canadian surgeon and NASA astronaut, and Dr. Mehran Anvari of McMaster University in Toronto, who conducted the NEEMO project. The future of such projects will require significant national and international investments to enable the performance of advanced surgical procedures during long space or un-

derwater missions or to bring advanced invasive procedures to populations in remote and distant locations.

## **CURRENT DEVELOPMENTS AND CHALLENGES IN OPERATING ROOM TRANSFORMATION**

Research platforms and OR laboratories are being established in many centers around the world, where new prototypes can be developed and tested under safe conditions and to devise treatment strategies and paradigms that will result in better and safer patient care.

Improved design of ORs and more efficient logistics are being developed using a multidisciplinary approach with close collaboration among clinicians, technologists, scientists, and industry. Real-time workflow process improvement initiatives are being implemented that combine parallel processing, novel information technology architecture, and asset management and patient tracking solutions. Clinical decision support systems combine patient-specific data with intelligent devices to create a perioperative zone of safety. Open plug-and-play standards for medical devices and analysis of outcomes provide the opportunity to implement "evidence-based" OR facility design and technology integration. Training health care personnel in the use and care of electromedical equipment improves performance, reduces downtime, and enhances safety. Hybrid ORs allow surgeons to perform combined open, minimally invasive, image-guided and/or catheter-based procedures in the same OR in the same operative setting.

Advanced image-guided surgery and a growing array of interventional procedures require the development of advanced visualization technologies that include enhanced acquisition, registration segmentation, and augmented-reality systems. OR imaging systems will be controlled at the OR table to provide faster, more accurate 3-dimensional imaging of the body. The C-arm, computed tomography, or iMRI (interventional Magnetic Resonance Imaging) will provide real-time or semi—real-time data during the procedure despite movement that may occur during a surgical procedure. This may require several imaging systems, as well as a sophisticated surgical table or conveyor that moves patients between stations. High-definition, 3-dimensional, real-time image guidance will allow the surgical team to remove tumors more effectively. The surgeon will be able to visualize internal organs from various perspectives with access to more anatomic details, including the most minute vessels, than ever possible before. Augmented-reality systems will allow the visual-

ization of volumetric information projected directly on the patient's organ during the operation. The internal pathology of solid organs will be visualized without having to cut into them using remote wireless and overlaid virtual images to guide the surgical interventionalist.<sup>3</sup>

Although more fixed imaging equipment may be installed in surgical suites in the near term, future advancements in image acquisition and software modeling will likely reduce that need. Ultimately, in the more distant future, advances in robotics and nanotechnologies will allow minimally invasive or noninvasive procedures to be performed in the physician's office. Hospitals could face having to retrofit procedure rooms for other uses.

## **THE ROLE OF SIMULATION**

The necessary components of the image-guided surgery revolution will enable personalized simulation, preprocedural planning, and rehearsal of the intended surgical intervention within the specific anatomic environment of the individual patient. Surgical planning will be more specific and treatment more targeted. A truly simulated environment allows the real workflows and processes of an actual OR to be mimicked, tested, and modified to fit the needs of the patient and optimize the performance of the actual surgical team. Simulation will be used to test how people react to human-machine interfaces. It is possible to understand whether new technology and processes impede or improve workflows, whether new issues are created, or whether safety and performance will be improved.

The use of simulation will become a requirement not only for teaching and staff training to shorten learning curves

and improve performance and outcomes but also to test concepts and systems before their introduction to determine how best to adopt and deploy new technology. Surgeons must embrace and exploit the use of simulation to improve performance and outcomes for our patients or face the reality that the payers and legal system will mandate its adoption.<sup>4</sup>

We have provided a brief overview of current trends and how they are likely to transform surgical care in the future. The future is exciting, and technology has much to offer. However, we must remember that teamwork, open communication, and a willingness to adapt and adopt new skills and processes are critical components to achieving better clinical outcomes. This editorial should serve as an appetizer to stimulate discussion and raise awareness regarding the current speedy revolutionary trends.

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